Wave/Energy Equation Problems

1. What is the wavelength of light that has a frequency of $1.20 \times 10^{13} s^{-1}$?

$\lambda = \frac{c}{\nu} = \frac{3.00 \times 10^{8} \frac{m}{s}}{1.20 \times 10^{13} \frac{1}{s}} = \boxed{2.50 \times 10^{-5} m}$

2. Ham radio operators often broadcast on the 6-meter band. The frequency of this electromagnetic radiation is __________ MHz.

$\nu = \frac{c}{\lambda} = \frac{3.00 \times 10^{8} \frac{m}{s}}{6m} \times \frac{1 MHz}{1 \times 10^{6} Hz} = \boxed{50 MHz}$

3. What is the wavelength of light in nm that has a frequency of $3.22 \times 10^{14} s^{-1}$?

$\lambda = \frac{3.00 \times 10^{8} \frac{m}{s}}{3.22 \times 10^{14} \frac{1}{s}} \times \frac{1 nm}{1 \times 10^{-9} m} = \boxed{932 nm}$

4. What is the wavelength of a photon that has an energy of $5.25 \times 10^{-19} J$?

$\lambda = \frac{hc}{E} = \frac{(6.62 \times 10^{-34} J \cdot s)(3.00 \times 10^{8} \frac{m}{s})}{5.25 \times 10^{-19} J} \times \frac{1 nm}{1 \times 10^{-9} m} = \boxed{378 nm}$

5. The energy of a photon that has a wavelength of 12.3 nm is __________ J.

$E = \frac{hc}{\lambda} = \frac{(6.62 \times 10^{-34} J \cdot s)(3.00 \times 10^{8} \frac{m}{s})}{12.3 nm \times \frac{1 m}{1 \times 10^{9} nm}} = \boxed{1.61 \times 10^{-17} J}$

6. Suppose that a microwave oven uses photons with an energy of 1.42×10^{-23} joules to provide you with a cooked popcorn snack. Determine the wavelength and frequency of the microwaves.

$\nu = \frac{1.42 \times 10^{-23} J}{6.62 \times 10^{-34} J s} = 2.14 \times 10^{10} Hz$ $\quad \lambda = \frac{(6.62 \times 10^{-34} J \cdot s)(3.00 \times 10^{8} \frac{m}{s})}{1.42 \times 10^{-23} J} = 0.0140 m$

7. The wavelength of the laser light that allows you to listen to your favorite tunes on a CD player lies in the red area of the visible spectra. If *one mole* of the photons delivers 1.54×10^{5} J, what is the frequency of this useful energy? Do people even still listen to CDs?

$1.54 \times 10^{5} \frac{J}{mol} \times \frac{1 mol\ phot}{6 \times 10^{23} phot} = \boxed{2.56 \times 10^{-19} \frac{J}{phot}}$ $\quad \nu = \frac{2.56 \times 10^{-19} J}{6.62 \times 10^{-34} J \cdot s} = \boxed{3.88 \times 10^{14} \frac{1}{s}}$

8. A mole of red photons of wavelength 725 nm has how many kJ of energy?

$E = \frac{(6.62 \times 10^{-34} J s)(3.00 \times 10^{8} \frac{m}{s})}{(725 nm \times \frac{1 m}{1 \times 10^{9} nm})} = 2.74 \times 10^{-19} \frac{J}{photon} \times \frac{6 \times 10^{23} phot}{1 mol\ ph} = \boxed{1.65 \times 10^{5} \frac{J}{mol\ photon}}$

9. It takes 254 kJ/mol to eject electrons from a certain metal surface. What is the longest wavelength of light (nm) that can be used to eject electrons from the surface of this metal via the photoelectric effect?

$254 \frac{kJ}{mol} \times \frac{1 mol\ pho}{6 \times 10^{23} pho} = 4.22 \times 10^{-22} \frac{kJ}{pho} \times \frac{1000 J}{1 kJ} = 4.22 \times 10^{-19} J$

$\lambda = \frac{(6.62 \times 10^{-34} J \cdot s)(3.00 \times 10^{8} \frac{m}{s})}{4.22 \times 10^{-19} J} \times \frac{1 nm}{1 \times 10^{-9} m} = \boxed{471 nm}$

10. If the metal used in problem 9 is hit with light with a frequency of 8.35x10^{14} hz, what will be the velocity of ejected electron?

$\nu_0 = \frac{c}{\lambda} = \frac{3.00\times10^8 \frac{m}{s}}{4.71\times10^{-7} m} = \boxed{6.37\times10^{14} hz}$

$\frac{1}{2} m v^2 = h(\nu - \nu_0)$

$V = \sqrt{\frac{2h(\nu-\nu_0)}{m}} = \sqrt{\frac{2(6.62\times10^{-34} \frac{kg\,m^2}{s})(8.35\times10^{14}\frac{1}{s} - 6.37\times10^{14}\frac{1}{s})}{(9.104\times10^{-31} kg)}}$

$\boxed{V = 5.37\times10^5 \frac{m}{s}}$

11. If you dropped your textbook, you might claim that "it is difficult to hold on to waves" with some validity. After all, mass does possess wave-like properties. However, what would be the wavelength of a 855g textbook moving 9.8 m/s?

$\lambda = \frac{h}{mV} = \frac{6.62\times10^{-34} \frac{kg\,m^2}{s}}{0.855 kg \; 9.8 \frac{m}{s}} = \boxed{7.91\times10^{-35} m}$

12. At what speed (m/s) must a 10 mg object be moving to have a de Broglie wavelength of 3.3 × 10^{-41} m?

$V = \frac{h}{m\lambda} = \frac{6.62\times10^{-34} \frac{kg\,m^2}{s}}{(10mg \times \frac{1kg}{1\times10^6 g})(3.3\times10^{-41} m)} = \boxed{2.0\times10^{12} \frac{m}{s}}$

13. The de Broglie wavelength of an electron is 8.7 × 10^{-11} m. The mass of an electron is 9.1 × 10^{-31} kg. What is the velocity of this electron? What is the frequency of this electron?

$V = \frac{h}{m\lambda} = \frac{6.62\times10^{-34} \frac{kg\,m^2}{s}}{(8.7\times10^{-11} m)(9.1\times10^{-31} kg)} = \boxed{8.36\times10^6 \frac{m}{s}}$

$\nu = \frac{c}{\lambda} = \frac{8.36\times10^6 \frac{m}{s}}{8.7\times10^{-11} m} = \boxed{9.6\times10^{16} \frac{1}{s}}$

14. Diffraction is known to be a characteristic of waves. Yet, when electrons, with mass, pass through the openings in crystals a diffraction pattern appears. Which of the following is consistent with this information?

1. Diffraction patterns are caused as the waves exhibit destructive interference only. Electrons annihilate each other.
2. Electrons and EM radiation produce diffraction patterns meaning mass must have wavelike properties and waves must have mass.
3. Electrons can exhibit diffraction patterns because as they pass through the regular patterns of openings in crystals they get lodged in the crystal causing light to be emitted.
4. Mass and wavelength are directly related. The small mass of an electron allows it to have a small enough wavelength to cause diffraction

15. Our understanding of electromagnetic radiation (EM) played a critical role in our understanding of atomic structure. Compare red light, blue light, and x-rays and arrange them in order so that the longest wavelength is first, highest frequency is second, and finally the highest energy is at the end of the list.

1. X-ray; x-rays; x-rays
2. Red; x-rays; blue
3. Blue; x-rays; red
4. Red; x-rays; x-rays

Quantum Theory Questions
For the following questions choose the best orbital from the list given to complete each statement.

1s 3s 3p 3d 3f 4s $4p_y$ 5s 5p $5p_x$ $5d_{xy}$ $5d^2$

1. An electron in a(n) __1s__ subshell experiences the greatest effective nuclear charge in a many-electron atom.

2. A tin atom has 50 electrons. Electrons in the __5p__ subshell experience the lowest effective nuclear charge.

3. This orbital does not exist. __3f__

4. In a hydrogen atom, an electron in a __1s__ orbital can absorb a photon, but cannot emit a photon.

5. The __3p 5p__ subshell contains three orbitals.

6. In which orbital does an electron in a phosphorus atom experience the greatest shielding __3p__?

7. In a ground-state manganese atoms, the __3d__ subshell is partially filled.

8. The __5px__ orbital is degenerate with $5p_y$ in a many-electron atom.

Write out the ground state electron configuration of copper, scandium, and platinum. How many valence electrons do each have?

Cu $1s^2 2s^2 2p^6 3s^2 3p^6 4s^1 3d^{10}$ 1

Sc $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^1$ 2

Pt $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6 4d^{10} 4f^{14} 5s^2 5p^6 6s^2 5d^8$ 2

$6s^1 5d^9$

?

What are the possible values of all four quantum numbers for each electron in a magnesium atom?

$_{12}Mg$	1	2	3	4	5	6	7	8	9	10	11	12
n	1	1	2	2	2	2	2	2	2	2	3	3
l	0	0	0	0	1	1	1	1	1	1	0	0
m_l	0	0	0	0	-1	0	1	-1	0	1	0	0
m_s	$+\frac{1}{2}$	$-\frac{1}{2}$	$+\frac{1}{2}$	$-\frac{1}{2}$	$+\frac{1}{2}$	$+\frac{1}{2}$	$+\frac{1}{2}$	$-\frac{1}{2}$	$-\frac{1}{2}$	$-\frac{1}{2}$	$+\frac{1}{2}$	$-\frac{1}{2}$

Draw the orbital diagram for the vanadium atom.

1s	2s	2p	3p	3s	3p	4s	3d
↑↓	↑↓	↑↓ ↑↓ ↑↓	↑↓ ↑↓ ↑↓	↑↓	↑↓ ↑↓ ↑↓	↑↓	↑ ↑ ↑ _ _

Questions

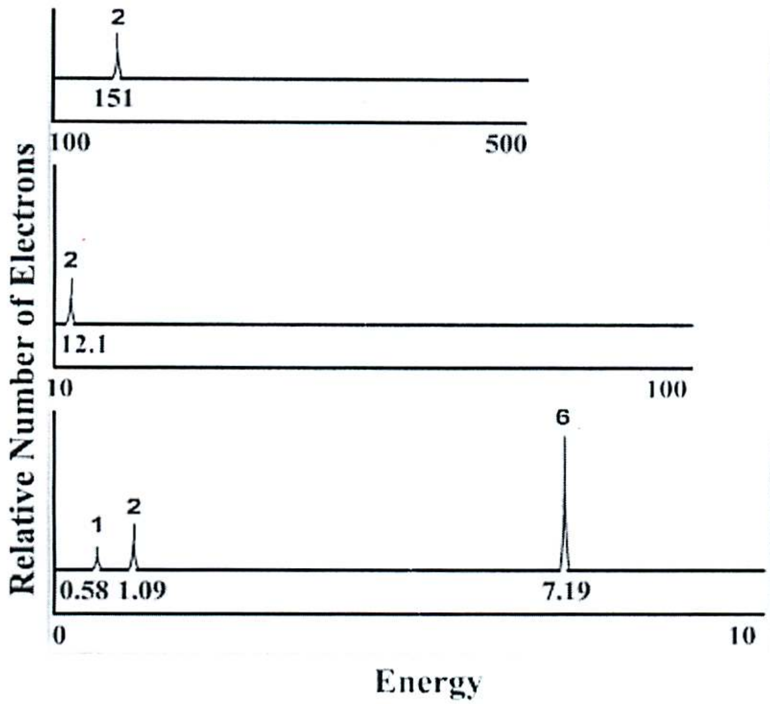
1. What determines the position and the height (intensity) of each peak in a photoelectron spectrum?

Position : Amount of E Required to Remove the e⁻ which is based on nuclear charge attraction of e⁻
Height : # of e⁻ in the orbital

2. Why is the distance of the energy level from the nucleus important in determining the corresponding peak position in the photoelectron spectrum?

The closer to the nucleus the E level is the more E Required to Remove it.

3. a. The spectrum below is for which element? Explain your reasoning.



Aluminum, b/c it has 13 e⁻ which is what the spectra shows.

b. Write the electron configuration for this element.

$1s^2 2s^2 2p^6 3s^2 3s^1$

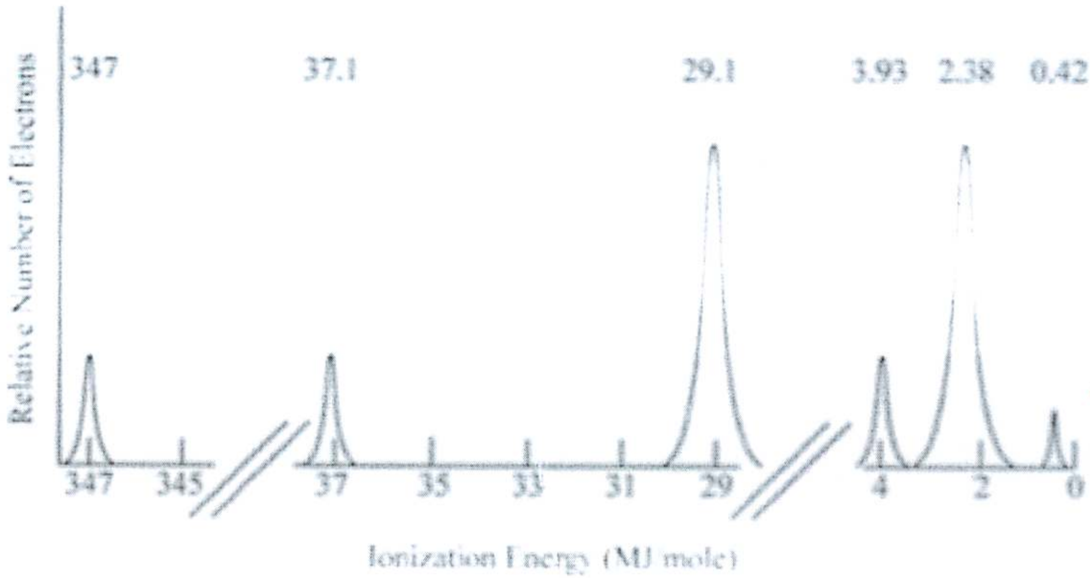
4. Identify if either of the following statements is correct. If yes, why? If not, why not?

a. The photoelectron spectrum of Mg^{2+} is expected to be identical to the photoelectron spectrum of Ne.

No They have different nuclear charges so positions of the peaks will be different

b. The photoelectron spectrum of ^{35}Cl is identical to the photoelectron spectrum of ^{37}Cl.

Yes They have the same nuclear charge

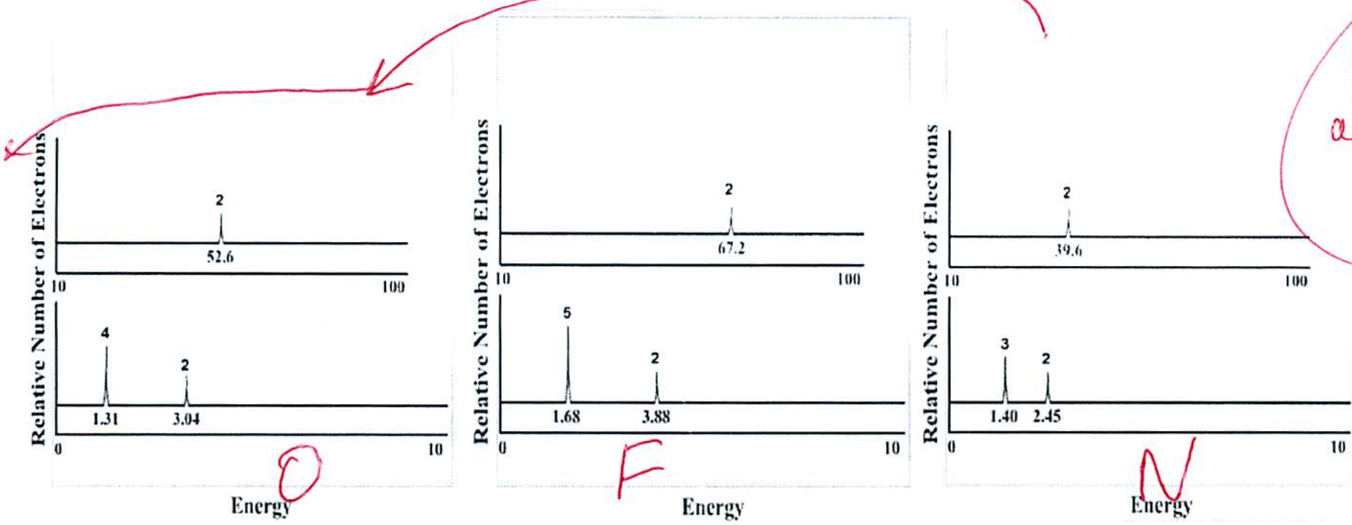


← 0.42 MJ/mol

5. For the PES spectrum of potassium above, explain why is the peak at 0.42 MJ/mol identified as being in the 4th energy level.

B/c it requires the least amount of E to ~~Be~~ remove ~~that~~ e⁻ it must be in the highest E level of K's lost e⁻. This is the 4s e⁻

ok on actual wksht



The spectra above are for nitrogen, oxygen, and fluorine respectively. What is the general trend for ionization energy across a period? When looking at the above spectra, does this trend hold true? Explain why, why not.

Gen Trend Across Period IE ↑

No There is a drop in IE of the 2p e⁻'s from 1.40 → 1.31 → 1.68.

This is b/c w/ O the ~~first~~ last e⁻ added is the first one doubled in the p orbital so there is a small amount of repulsion so less E is there is a drop in IE.